US006735715B1

(12) **United States Patent**
Graham

(10) **Patent No.: US 6,735,715 B1**
(45) **Date of Patent: May 11, 2004**

(54) **SYSTEM AND METHOD FOR OPERATING A SCSI BUS WITH REDUNDANT SCSI ADAPTORS**

(75) Inventor: **Simon P. Graham**, Bolton, MA (US)

(73) Assignee: **Stratus Technologies Bermuda Ltd.**, Hamilton (BM)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/548,530**

(22) Filed: **Apr. 13, 2000**

(51) **Int. Cl.**[7] **G06F 11/00**
(52) **U.S. Cl.** **714/9**; 714/43
(58) **Field of Search** 714/43, 56, 2, 714/3, 9; 710/100, 120, 119, 312, 311, 306

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,544,973	A	12/1970	Borck, Jr. et al.	340/172.5
3,548,176	A	12/1970	Shutler	235/153
3,641,505	A	2/1972	Artz et al.	340/172.5
3,710,324	A	1/1973	Cohen et al.	340/172.5
3,736,566	A	5/1973	Anderson et al.	340/172.5
3,795,901	A	3/1974	Boehm et al.	340/172.5
3,805,039	A	4/1974	Stiffler	235/153 AE
3,820,079	A	6/1974	Bergh et al.	340/172.5
3,840,861	A	10/1974	Amdahl et al.	340/172.5
3,997,896	A	12/1976	Cassarino, Jr. et al.	340/172.5
4,015,246	A	3/1977	Hopkins, Jr. et al.	340/172.5
4,032,893	A	6/1977	Moran	340/166 R
4,059,736	A	11/1977	Perucca et al.	179/175.2 R
4,228,496	A	10/1980	Katzman et al.	364/200
4,245,344	A	1/1981	Richter	371/68
4,263,649	A	4/1981	Lapp, Jr.	364/200
4,275,440	A	6/1981	Adams, Jr. et al.	364/200
4,309,754	A	1/1982	Dinwiddie, Jr. et al.	364/200
4,366,535	A	12/1982	Cedolin et al.	364/200
4,434,463	A	2/1984	Quinquis et al.	364/200
4,449,182	A	5/1984	Rubinson et al.	364/200

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

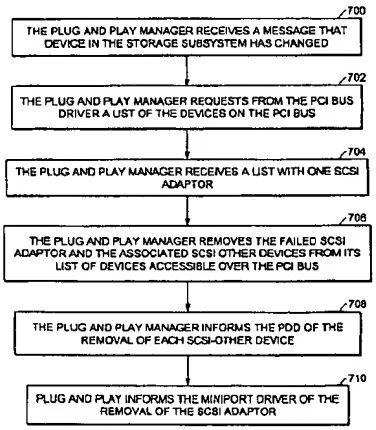
EP	0 299 700	7/1987	G06F/13/42
EP	0 301 499 A2	2/1989	G06F/11/16
EP	0 428 330 A2	5/1991	G06F/13/30
EP	0 475 005 B1	11/1995	G06F/15/16
EP	0 293 860 B1	2/1996	G06F/13/28
EP	0772127 A1	5/1997	11/20
EP	0 390 567 B1	6/1999	H04L/29/06
GB	2 060 229 A2	4/1981	G06F/3/00

Primary Examiner—Robert Beausoliel
Assistant Examiner—Gabriel Chu
(74) *Attorney, Agent, or Firm*—Testa, Hurwitz & Thibeault, LLP

(57) **ABSTRACT**

A computer system includes a port duplex driver (PDD) that creates a "virtual SCSI adaptor," to control the operations of one or more redundant SCSI adaptors. During boot-up operations or when the status of a device on a SCSI bus changes, the PDD identifies the virtual SCSI adaptor as the only adaptor that provides access to particular storage devices on the SCSI bus. System components then direct data transfer operations through the virtual SCSI adaptor to the storage devices. The PDD intercepts commands that are directed through the virtual SCSI adaptor, and redirects the commands to a selected one of the actual SCSI adaptors. The selected SCSI adaptor then operates in a conventional manner, to translate the generic commands from the system components to device-specific commands for the storage devices on the SCSI bus. If the selected SCSI adaptor fails, the PDD redirects the data transfer operations instead through one of the redundant SCSI adaptors. The failure does not affect the remainder of the system, which continues to conduct data transfer operations through the virtual SCSI adaptor.

13 Claims, 8 Drawing Sheets



U.S. PATENT DOCUMENTS

4,453,215	A	6/1984	Reid	364/200
4,467,436	A	8/1984	Chance et al.	364/513
4,484,273	A	11/1984	Stiffler et al.	364/200
4,486,826	A	12/1984	Wolff et al.	364/200
4,503,496	A	3/1985	Holzner et al.	364/200
4,543,628	A	9/1985	Pomfret	364/200
4,590,554	A	5/1986	Glazer et al.	364/200
4,597,084	A	6/1986	Dynneson et al.	371/51
4,608,631	A	8/1986	Stiffler et al.	364/200
4,628,447	A	12/1986	Cartret et al.	364/200
4,630,193	A	12/1986	Kris	364/200
4,633,394	A	12/1986	Georgiou et al.	364/200
4,654,857	A	3/1987	Samson et al.	371/68
4,669,056	A	5/1987	Waldecker et al.	364/900
4,669,079	A	5/1987	Blum	370/85
4,700,292	A	10/1987	Campanini	364/200
4,703,420	A	10/1987	Irwin	364/200
4,750,177	A	6/1988	Hendrie et al.	371/32
4,805,091	A	2/1989	Thiel et al.	364/200
4,809,169	A	2/1989	Sfarti et al.	364/200
4,816,990	A	3/1989	Williams	364/200
4,827,409	A	5/1989	Dickson	364/200
4,866,604	A	9/1989	Reid	364/200
4,914,580	A	4/1990	Jensen et al.	364/200
4,916,695	A	4/1990	Ossfeldt	371/9.1
4,926,315	A	5/1990	Long et al.	364/200
4,931,922	A	6/1990	Baty et al.	364/200
4,939,643	A	7/1990	Long et al.	364/200
4,974,144	A	11/1990	Long et al.	364/200
4,974,150	A	11/1990	Long et al.	364/200
4,985,830	A	1/1991	Atac et al.	364/200
4,994,960	A	2/1991	Tuchler et al.	364/200
5,083,258	A	1/1992	Yamasaki	395/725
5,117,486	A	5/1992	Clark et al.	395/250
5,138,257	A	8/1992	Katsura	324/158 R
5,179,663	A	1/1993	Iimura	395/250
5,243,704	A	9/1993	Baty et al.	395/325
5,247,522	A	9/1993	Reiff	371/29.5
5,251,303	A	10/1993	Fogg, Jr. et al.	395/275
5,270,699	A	12/1993	Signaigo et al.	340/825.01
5,295,258	A	3/1994	Jewett et al.	395/575
5,313,627	A	5/1994	Amini et al.	395/575
5,317,726	A	5/1994	Horst	395/575
5,428,766	A	6/1995	Seaman	395/575
5,463,755	A	10/1995	Dumarot et al.	395/475
5,465,340	A	11/1995	Creedon et al.	395/846
5,537,535	A	7/1996	Maruyama et al.	395/183.01
5,546,535	A	8/1996	Stallmo et al.	714/9
5,550,986	A	8/1996	DuLac	395/280
5,555,372	A	9/1996	Tetreault et al.	395/182.13
5,574,865	A	11/1996	Hashemi	395/283
5,584,030	A	12/1996	Husak et al.	395/750
5,600,784	A	2/1997	Bissett et al.	395/182.1
5,613,162	A	3/1997	Kabenjian	395/842
5,627,965	A	5/1997	Liddell et al.	395/185.01
5,630,056	A	5/1997	Horvath et al.	395/185.09
5,659,681	A	8/1997	Ojima	395/183.19
5,671,443	A	9/1997	Stauffer et al.	395/845
5,696,905	A	12/1997	Reimer et al.	395/227
5,701,410	A	12/1997	BeMent et al.	395/183.19
5,701,457	A	12/1997	Fujiwara	395/608
5,737,601	A	4/1998	Jain et al.	395/617
5,751,955	A	5/1998	Sonnier et al.	395/200.19
5,758,065	A	5/1998	Reams et al.	395/185.01
5,790,397	A	8/1998	Bissett et al.	364/131
5,790,775	A *	8/1998	Marks et al.	714/9
5,809,256	A	9/1998	Najemy	395/283
5,809,285	A	9/1998	Hilland	703/25
5,812,748	A	9/1998	Ohran et al.	395/182.02
5,815,647	A	9/1998	Buckland et al.	395/182.01
5,828,903	A	10/1998	Sethuram et al.	395/817
5,838,899	A	11/1998	Leavitt et al.	395/185.09
5,838,900	A	11/1998	Horvath et al.	395/185.09
5,838,993	A	11/1998	Riley et al.	395/842
5,862,145	A	1/1999	Grossman et al.	371/5.1
5,875,308	A	2/1999	Egan et al.	395/283
5,875,351	A	2/1999	Riley	395/842
5,881,251	A	3/1999	Fung et al.	395/283
5,892,928	A	4/1999	Wallach et al.	395/283
5,894,560	A	4/1999	Carmichael et al.	395/845
5,903,778	A	5/1999	Chang	395/882
5,928,339	A	7/1999	Nishikawa	710/26
5,944,800	A	8/1999	Mattheis et al.	710/23
5,953,538	A	9/1999	Duncan et al.	395/842
5,956,476	A	9/1999	Ranson et al.	395/183.06
5,978,866	A	11/1999	Nain	710/22
5,982,672	A	11/1999	Moon et al.	365/189.01
5,983,289	A	11/1999	Ishikawa et al.	710/35
5,991,844	A *	11/1999	Khosrowpour	710/312
5,991,900	A	11/1999	Garnett	714/56
5,996,035	A	11/1999	Allen et al.	710/103
6,000,043	A	12/1999	Abramson	714/44
6,009,481	A	12/1999	Mayer	710/33
6,009,535	A	12/1999	Halligan et al.	714/5
6,012,119	A *	1/2000	Ninomiya et al.	710/305
6,012,120	A	1/2000	Duncan et al.	710/129
6,021,456	A	2/2000	Herdeg et al.	710/260
6,026,458	A	2/2000	Rasums	710/103
6,032,201	A	2/2000	Tillery, Jr. et al.	710/8
6,032,271	A	2/2000	Goodrum et al.	714/56
6,041,375	A	3/2000	Bass et al.	710/103
6,047,343	A	4/2000	Olarig	710/102
6,049,894	A	4/2000	Gates	714/41
6,052,795	A *	4/2000	Murotani et al.	714/3
6,055,584	A	4/2000	Bridges et al.	710/27
6,062,480	A	5/2000	Evoy	235/492
6,073,196	A	6/2000	Goodrum et al.	710/103
6,085,333	A	7/2000	DeKoning et al.	714/7
6,098,137	A	8/2000	Goodrum et al.	710/129
6,125,417	A	9/2000	Bailis et al.	710/103
6,128,750	A *	10/2000	Espy et al.	714/7
6,141,769	A	10/2000	Petivan et al.	714/10
6,154,802	A *	11/2000	Khosrowpour	710/312
6,185,697	B1 *	2/2001	Shiraishi	714/6
6,202,115	B1 *	3/2001	Khosrowpour	710/312
6,324,627	B1	11/2001	Kricheff et al.	711/163
6,363,448	B1 *	3/2002	Waller et al.	710/312
6,430,710	B1 *	8/2002	Moriyama et al.	714/43
6,449,731	B1 *	9/2002	Frey, Jr.	714/9
6,519,671	B1 *	2/2003	Kondou et al.	710/311
6,563,595	B1 *	5/2003	Galloway	358/1.1

* cited by examiner

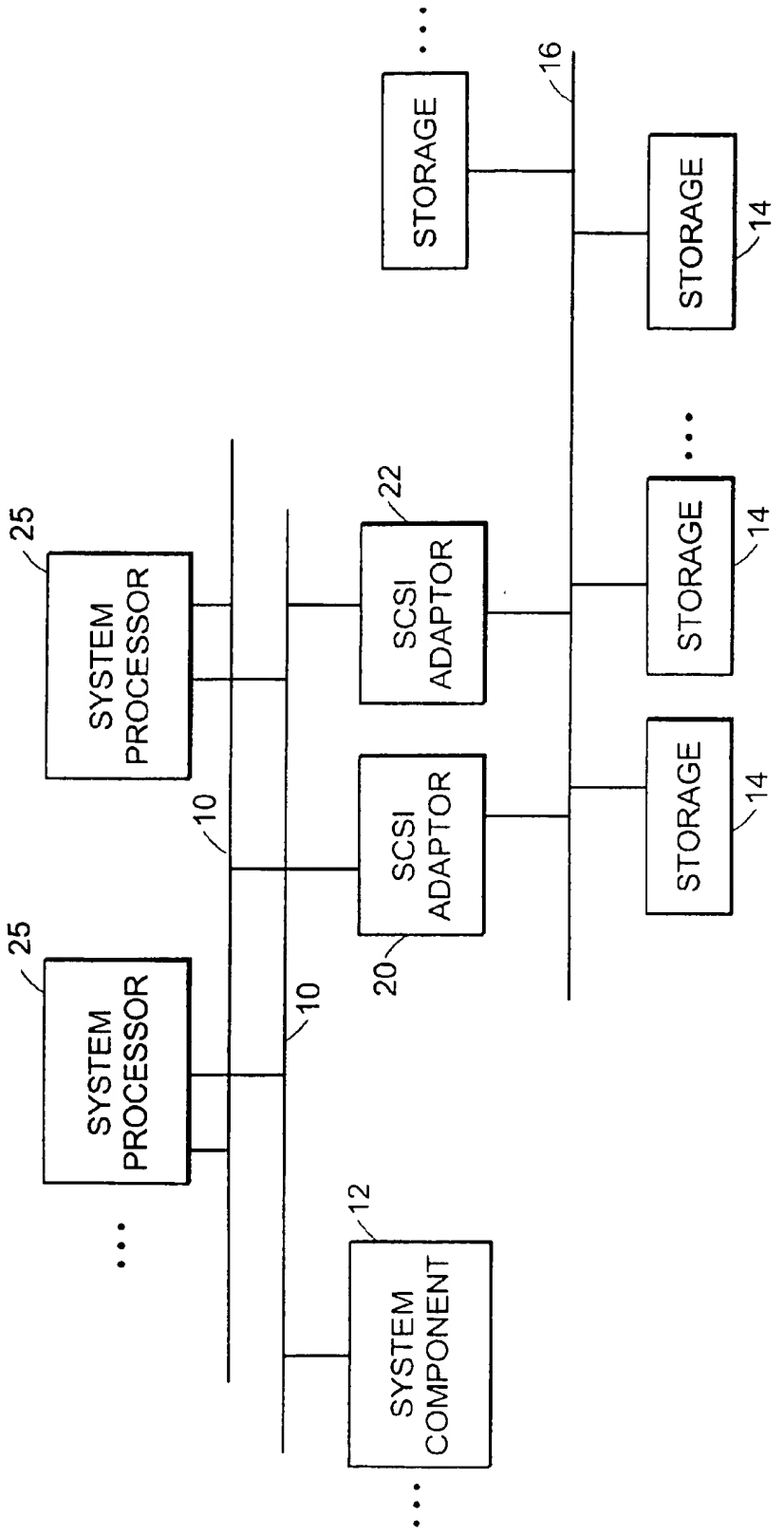

STORAGE
16
STORAGE
14
STORAGE
14
STORAGE
14
22
SCSI ADAPTOR
SCSI ADAPTOR
20
25
SYSTEM PROCESSOR
25
SYSTEM PROCESSOR
10
10
12
SYSTEM COMPONENT

FIG. 1

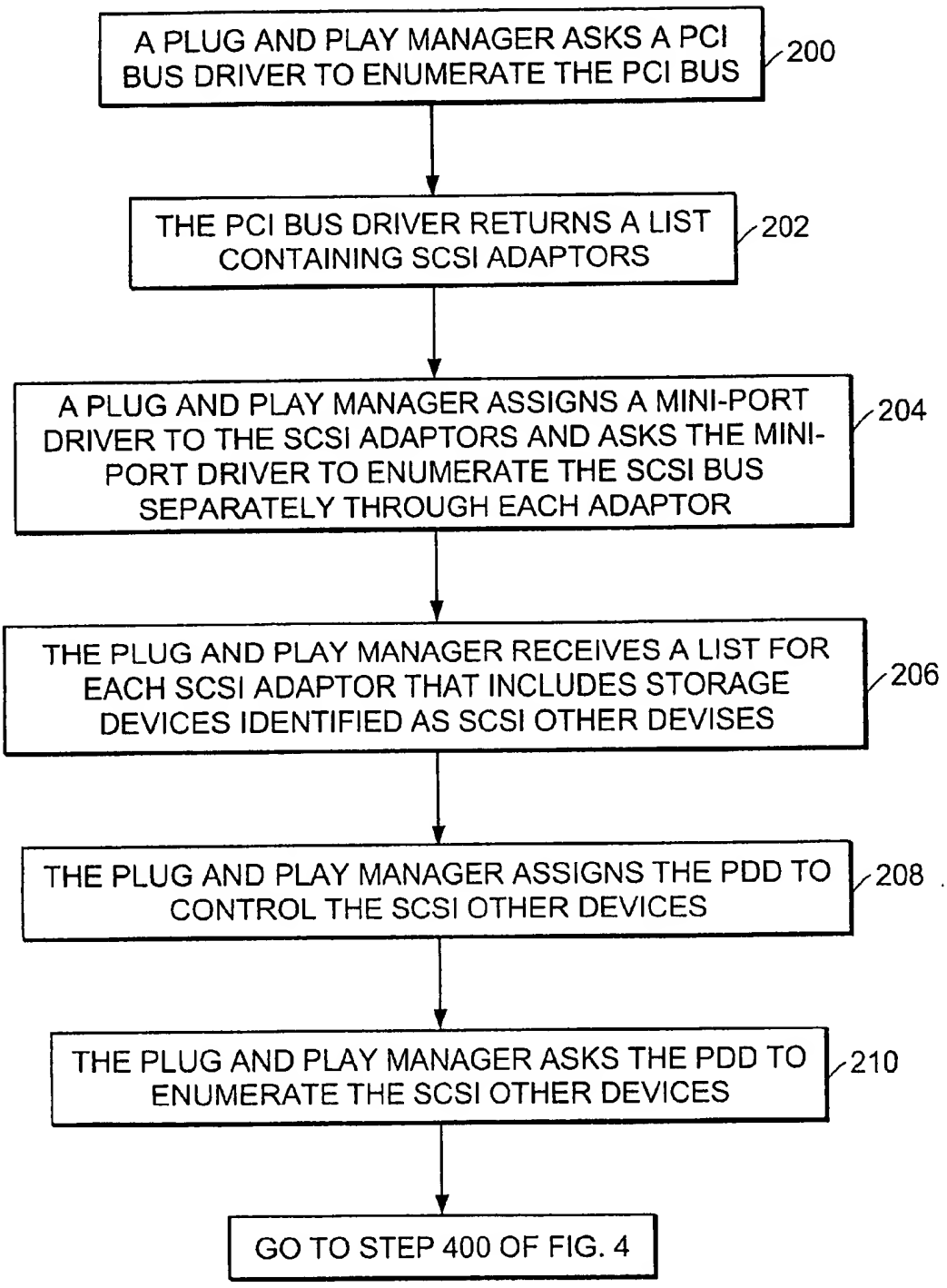

A PLUG AND PLAY MANAGER ASKS A PCI BUS DRIVER TO ENUMERATE THE PCI BUS
200
THE PCI BUS DRIVER RETURNS A LIST CONTAINING SCSI ADAPTORS
202
A PLUG AND PLAY MANAGER ASSIGNS A MINI-PORT DRIVER TO THE SCSI ADAPTORS AND ASKS THE MINI-PORT DRIVER TO ENUMERATE THE SCSI BUS SEPARATELY THROUGH EACH ADAPTOR
204
THE PLUG AND PLAY MANAGER RECEIVES A LIST FOR EACH SCSI ADAPTOR THAT INCLUDES STORAGE DEVICES IDENTIFIED AS SCSI OTHER DEVISES
206
THE PLUG AND PLAY MANAGER ASSIGNS THE PDD TO CONTROL THE SCSI OTHER DEVICES
208
THE PLUG AND PLAY MANAGER ASKS THE PDD TO ENUMERATE THE SCSI OTHER DEVICES
210
GO TO STEP 400 OF FIG. 4

FIG. 2

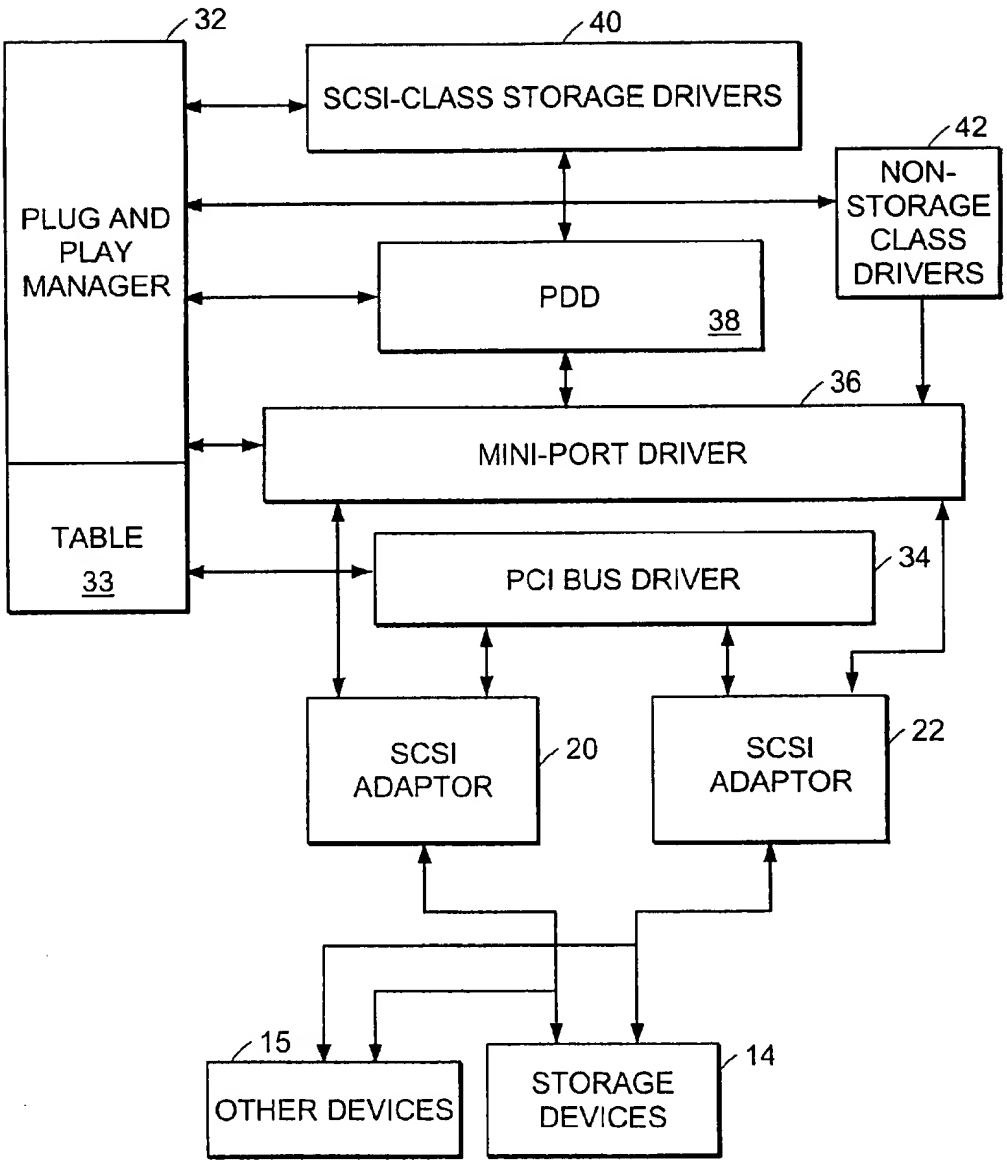

32
40
SCSI-CLASS STORAGE DRIVERS
42
NON-STORAGE CLASS DRIVERS
PLUG AND PLAY MANAGER
PDD
38
36
MINI-PORT DRIVER
TABLE
33
PCI BUS DRIVER
34
SCSI ADAPTOR
20
SCSI ADAPTOR
22
15
OTHER DEVICES
STORAGE DEVICES
14

FIG. 3

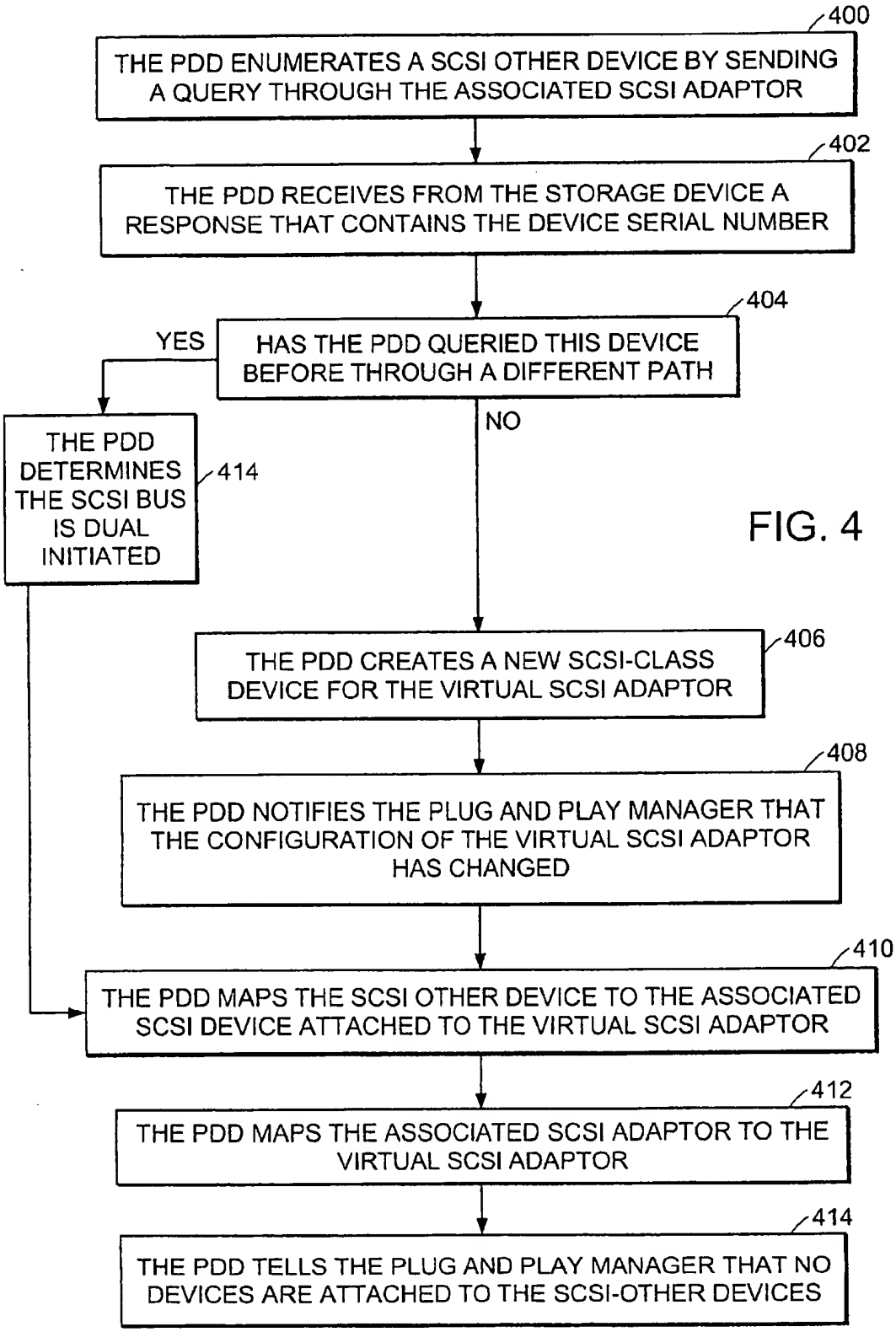

400
THE PDD ENUMERATES A SCSI OTHER DEVICE BY SENDING A QUERY THROUGH THE ASSOCIATED SCSI ADAPTOR
402
THE PDD RECEIVES FROM THE STORAGE DEVICE A RESPONSE THAT CONTAINS THE DEVICE SERIAL NUMBER
404
HAS THE PDD QUERIED THIS DEVICE BEFORE THROUGH A DIFFERENT PATH
YES
NO
THE PDD DETERMINES THE SCSI BUS IS DUAL INITIATED
414
406
THE PDD CREATES A NEW SCSI-CLASS DEVICE FOR THE VIRTUAL SCSI ADAPTOR
408
THE PDD NOTIFIES THE PLUG AND PLAY MANAGER THAT THE CONFIGURATION OF THE VIRTUAL SCSI ADAPTOR HAS CHANGED
410
THE PDD MAPS THE SCSI OTHER DEVICE TO THE ASSOCIATED SCSI DEVICE ATTACHED TO THE VIRTUAL SCSI ADAPTOR
412
THE PDD MAPS THE ASSOCIATED SCSI ADAPTOR TO THE VIRTUAL SCSI ADAPTOR
414
THE PDD TELLS THE PLUG AND PLAY MANAGER THAT NO DEVICES ARE ATTACHED TO THE SCSI-OTHER DEVICES

FIG. 4

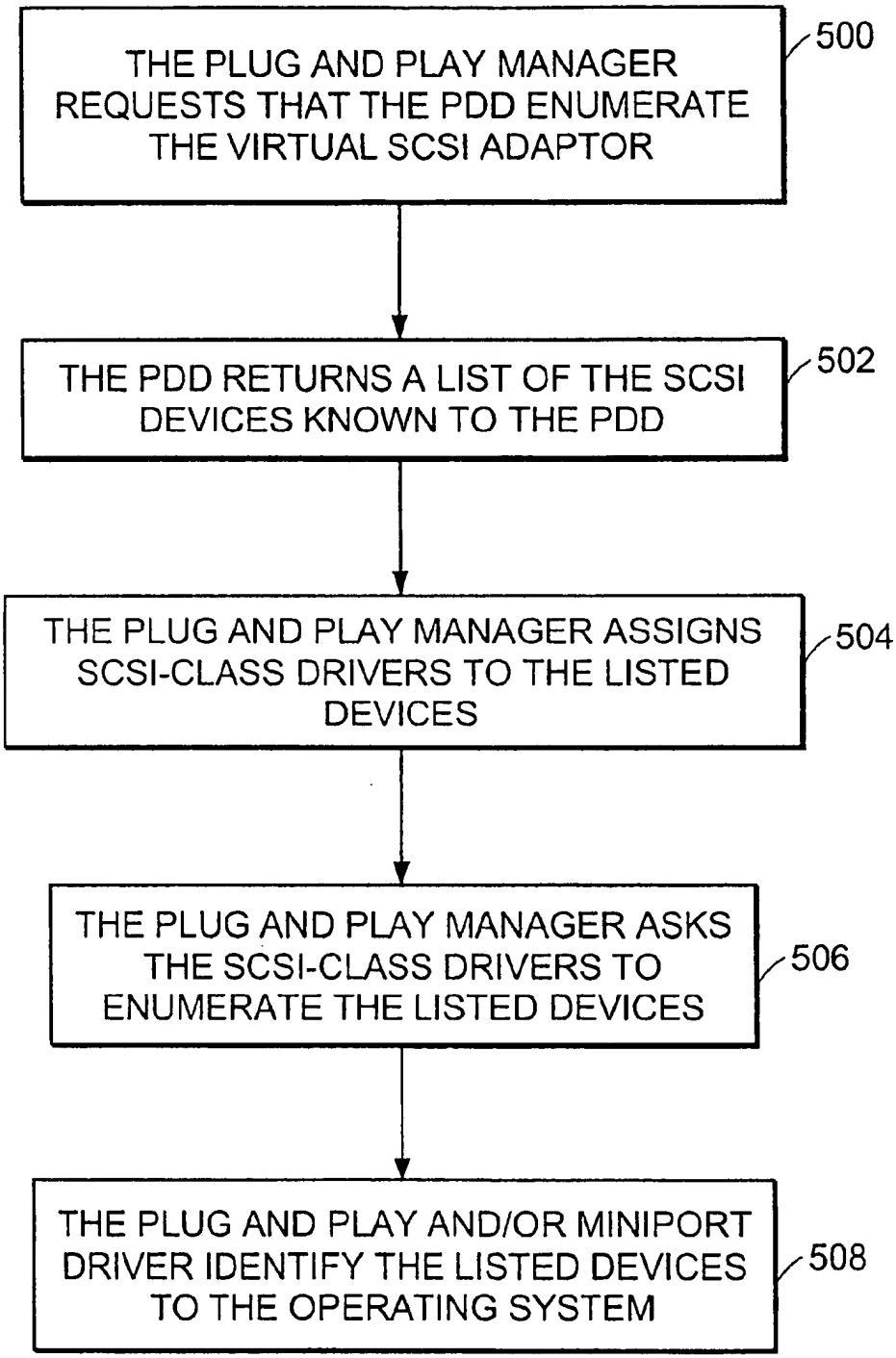

THE PLUG AND PLAY MANAGER REQUESTS THAT THE PDD ENUMERATE THE VIRTUAL SCSI ADAPTOR
500
THE PDD RETURNS A LIST OF THE SCSI DEVICES KNOWN TO THE PDD
502
THE PLUG AND PLAY MANAGER ASSIGNS SCSI-CLASS DRIVERS TO THE LISTED DEVICES
504
THE PLUG AND PLAY MANAGER ASKS THE SCSI-CLASS DRIVERS TO ENUMERATE THE LISTED DEVICES
506
THE PLUG AND PLAY AND/OR MINIPORT DRIVER IDENTIFY THE LISTED DEVICES TO THE OPERATING SYSTEM
508

FIG. 5

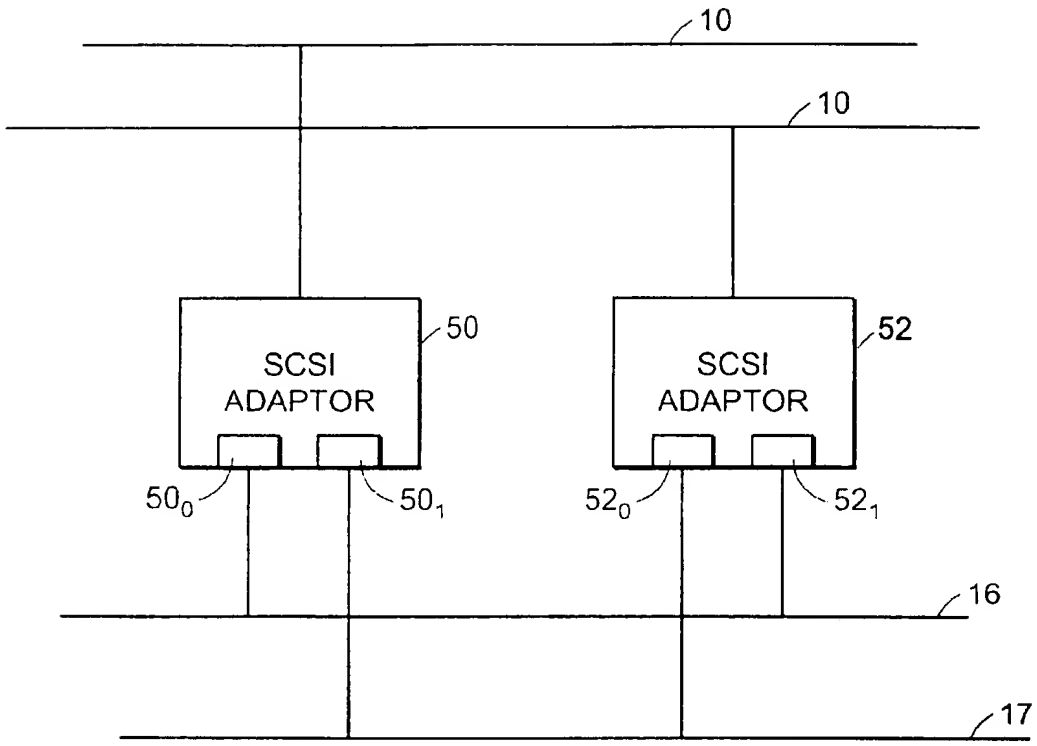


FIG. 6

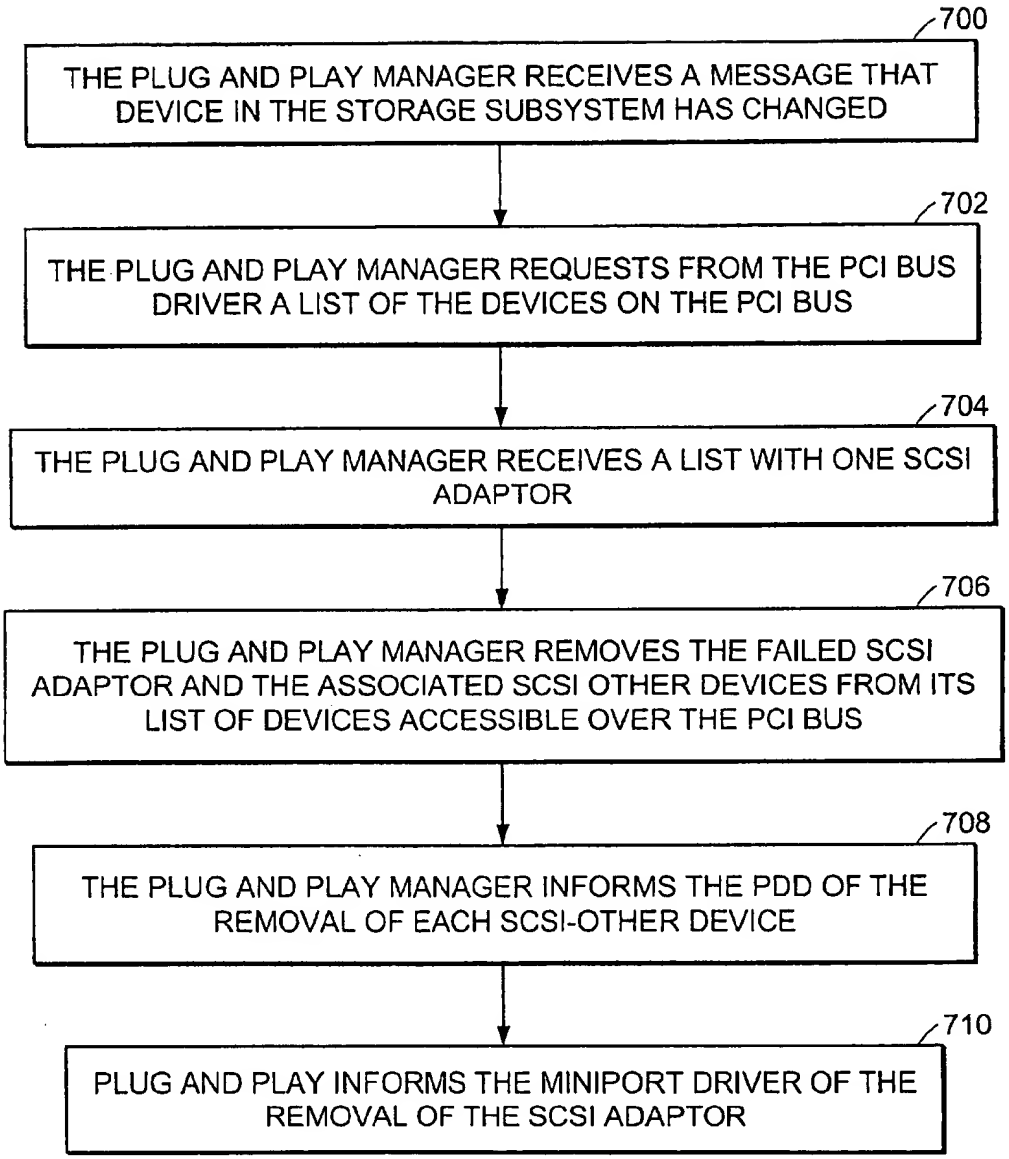

700
THE PLUG AND PLAY MANAGER RECEIVES A MESSAGE THAT DEVICE IN THE STORAGE SUBSYSTEM HAS CHANGED
702
THE PLUG AND PLAY MANAGER REQUESTS FROM THE PCI BUS DRIVER A LIST OF THE DEVICES ON THE PCI BUS
704
THE PLUG AND PLAY MANAGER RECEIVES A LIST WITH ONE SCSI ADAPTOR
706
THE PLUG AND PLAY MANAGER REMOVES THE FAILED SCSI ADAPTOR AND THE ASSOCIATED SCSI OTHER DEVICES FROM ITS LIST OF DEVICES ACCESSIBLE OVER THE PCI BUS
708
THE PLUG AND PLAY MANAGER INFORMS THE PDD OF THE REMOVAL OF EACH SCSI-OTHER DEVICE
710
PLUG AND PLAY INFORMS THE MINIPORT DRIVER OF THE REMOVAL OF THE SCSI ADAPTOR

FIG. 7

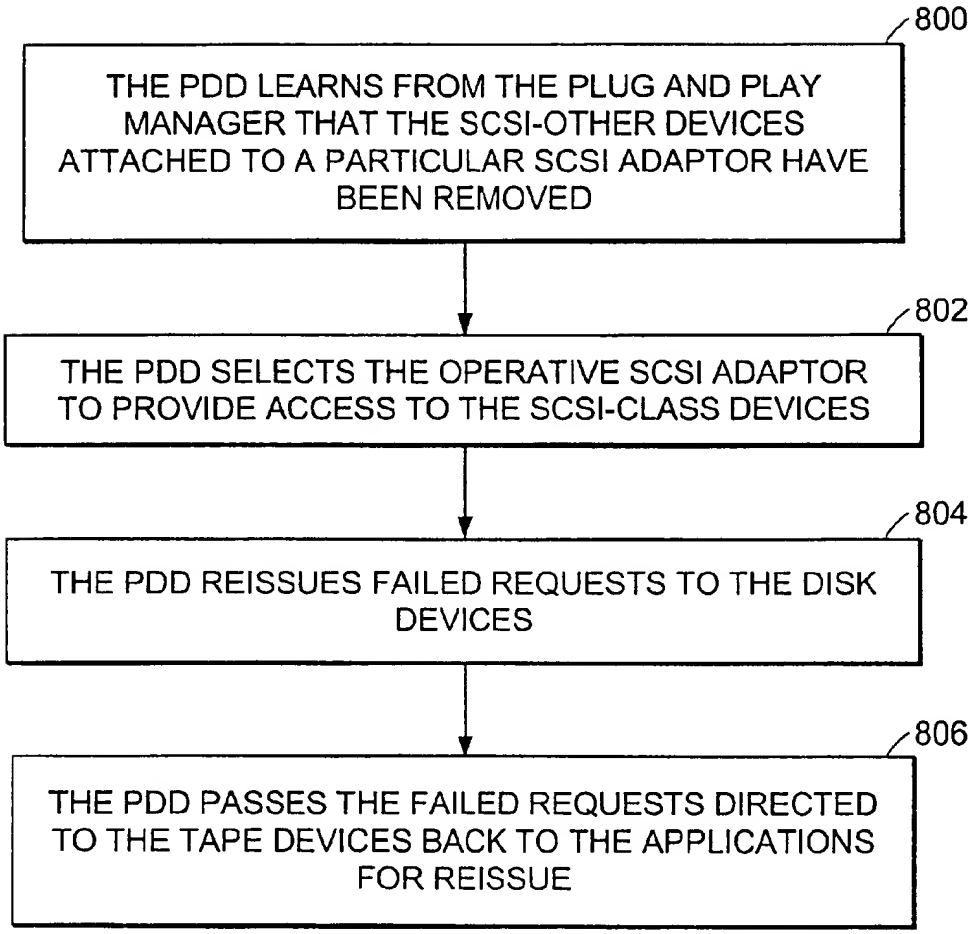

800
THE PDD LEARNS FROM THE PLUG AND PLAY MANAGER THAT THE SCSI-OTHER DEVICES ATTACHED TO A PARTICULAR SCSI ADAPTOR HAVE BEEN REMOVED
802
THE PDD SELECTS THE OPERATIVE SCSI ADAPTOR TO PROVIDE ACCESS TO THE SCSI-CLASS DEVICES
804
THE PDD REISSUES FAILED REQUESTS TO THE DISK DEVICES
806
THE PDD PASSES THE FAILED REQUESTS DIRECTED TO THE TAPE DEVICES BACK TO THE APPLICATIONS FOR REISSUE

FIG. 8

SYSTEM AND METHOD FOR OPERATING A SCSI BUS WITH REDUNDANT SCSI ADAPTORS

FIELD OF THE INVENTION

The invention relates generally to fault tolerant computer systems and, more particularly, to mechanisms for fault tolerant access to storage subsystems.

BACKGROUND OF THE INVENTION

Storage devices, such as disk drives, typically attach to and communicate with a computer system over a SCSI bus. Other devices, such as the key board and system processor, communicate with the storage devices over a system I/O bus such as a PCI bus. To facilitate communication between the devices on the two busses, a SCSI adaptor plugs into both busses. The SCSI adaptor is essentially a translator, which receives generic commands generated by the system components, and translates the commands to specialized commands for the particular storage devices that are attached to the SCSI bus. The system components thus have to know only the types, or classes, of storage devices available, and not the specifics of the devices.

During system boot-up, a SCSI port driver, either alone or in conjunction with a plug and play manager, identifies the devices that are accessible through the SCSI adaptor by relative location and class, e.g., disk or tape drive. If the system is operating in, for example, a Windows NT environment, the operating system then creates for the identified devices a set of device objects that can be used by the system components, to direct the generic data transfer commands to the respective storage devices.

To add fault tolerance to such a system, it is desirable to include in the system one or more additional SCSI adaptors that provide redundant paths from the PCI bus to the SCSI bus, and thus, to the storage devices. Adding the redundant SCSI adaptors to a system that uses Windows NT, however, causes the system to create additional sets of device objects for the storage devices. Specifically, the system creates one set that corresponds to the storage devices that are accessible through the first SCSI adaptor, a second set for the storage devices that are accessible through the second SCSI adaptor and so forth. Accordingly, each storage device is identified by multiple device objects, which may confuse or cause other problems for data transfer operations.

SUMMARY OF THE INVENTION

The inventive system includes a port duplex driver (PDD) that creates a "virtual SCSI adaptor," to control the operations of one or more conventional SCSI adaptors.

During boot-up operations or when the status of a device on the SCSI bus changes, the PDD identifies the virtual SCSI adaptor as the only adaptor that provides access to the storage devices on the SCSI bus. The system then assigns a single set of device objects to the storage devices and data transfer commands are directed to the storage devices through the virtual adaptors using the device objects. The PDD thereafter intercepts the commands that are directed through the virtual SCSI adaptor, and redirects them to a selected one of the actual SCSI adaptors. The selected SCSI adaptor then operates in a conventional manner, to translate the generic commands to device-specific commands for the storage devices, and so forth.

If the selected SCSI adaptor fails, the PDD redirects the data transfer operations instead through one of the redundant SCSI adaptors. The failure does not affect the remainder of the system, which continues to conduct data transfer operations through the virtual SCSI adaptor.

The PDD may create the virtual SCSI adaptor even for configurations in which a single SCSI adaptor is connected to the SCSI bus. In this way, one or more redundant SCSI adaptors may be added at a later time and mapped by the PDD to the existing virtual SCSI adaptor, without affecting the way in which the remainder of the system conducts data transfer operations.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention description below refers to the accompanying drawings, of which:

FIG. **1** is a functional block diagram of a system constructed in accordance with the invention;

FIG. **2** is a flow chart of boot-up operations of the system;

FIG. **3** is a more detailed functional block diagram of the system;

FIGS. **4–5** are more detailed flow charts of the operations system of FIG. **1**;

FIG. **6** is a functional block diagram of an alternative SCSI adaptor in the systems of FIG. **1**;

FIG. **7** is a flow chart of the operations of the system when a SCSI adaptor fails; and

FIG. **8** is a flow chart of the operations of a port duplex driver when a SCSI adaptor fails;

DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

Referring to FIG. **1**, a computer system includes an I/O bus **10** that handles communications for various system components **12**, such as, for example, a system processor. The I/O bus **10** in the exemplary system is a PCI bus. One or more storage devices **14**, such as disk drives and/or tape drives, that participate in data transfer operations with the system components **12** connect to the system over a SCSI bus **16**. Two SCSI adaptors **20** and **22** interconnect the I/O bus **10** and the SCSI bus **16**, to provide redundant paths for communications between the system components **12** and the storage devices **14**. This configuration of the SCSI bus is referred to herein as"dual initiated" SCSI bus. If only a single SCSI adaptor **20** is included in the system, the configuration is instead referred to as a "single initiated" SCSI bus. As depicted in the drawing, the system includes redundant system processors **25** and redundant I/O busses **10**, to provide fault tolerant operation of the system processors and the SCSI adaptors. the system processors in the exemplary system operate in lock-step, and thus, perform the same operations at the same times.

Referring also to FIGS. **2** and **3**, during system boot-up, a plug-and-play manager **32** that is connected to or resident on the system processor **12** calls on a PCI bus driver **34** to enumerate the devices on the PCI bus **10** (step **200**). The PCI bus driver queries the devices on the PCI bus and identifies the SCSI adaptors **21** and **22** to the plug and play manager (step **202**). The PCI bus driver will also identify any other devices (not shown) that are connected to the bus, however, for the following discussion these devices are not of interest.

Referring also to FIGS. **2** and **3**, during system boot-up, a plug-and-play manager **32** that is connected to or resident on the system processor **25** calls on a PCI bus driver **34** to enumerate the devices on the PCI bus **10** (step **200**). The PCI bus driver queries the devises on the PCI bus and identifies

the SCSI adaptors **20** and **22** to the plug and play manager (step **202**). The PCI bus driver will also identify any other devices (not shown) that are connected to the bus, however, for the following discussion these devices are not of interest.

The plug-and-play manager **32** consults a stored look-up table **33**, to determine which driver to assign to each SCSI adaptor **20** and **22**. Based on the contents of the table, the plug-and-play manager then assigns a port driver **36**, which is referred to herein also as a mini-port driver, to each SCSI adaptor **20** and **22**.

In steps **204** and **206**, the plug and play manager asks the mini-port driver to determine what is attached, for example, to the SCSI adaptor **20**, that is, to enumerate the devices on the SCSI bus through that adaptor. In response to the request from the plug-and-play manager **32**, the mini-port driver **36** sends queries to the devices on the SCSI bus **16**, by location through the SCSI adaptor **20**. The individual devices respond by sending back a response that indicates that the device is a storage device. The mini-port driver next returns to the plug and play manager a list of the devices associated with the SCSI adaptor **20**, and identifies each storage device on the list as a "SCSI other" device. The plug and play manager similarly requests that the mini-port driver **36** enumerate the devices on the SCSI bus through the SCSI adaptor **22**. The mini-port driver then queries the storage devices **14** through that adaptor. Each device responds to the query by sending back a response that indicates that the device is a storage device. The mini-port driver then returns a list of devices associated with the SCSI adaptor **20**, and similarly identifies each storage device on the list as a SCSI other device.

The plug and play manager **32** next enters the stored look-up table **33** to determine which drivers to assign to the various SCSI other devices. Based on the contents of the table **33**, the plug-and-play manager **32** assigns to each of the SCSI other devices a port duplex driver **38** (step **208**). The port duplex driver, or PDD, may be loaded at this time or it may have been pre-loaded during an earlier step in the boot-up operations When the PDD is loaded, it creates a "virtual SCSI adaptor" and identifies the virtual device to the plug-and-play manager.

As a further step in the device enumeration operation, the plug-and-play manager **32** issues for each SCSI other device a request that the PDD **38** list what is connected to the device (step **210**). In the example, the plug-and-play manager first requests enumeration of a particular SCSI other device that is connected to SCSI adaptor **20**.

The operations of the PDD **38** are discussed with reference to FIG. **4**. In response to a request from the plug-and-play manager **32**, the PDD enumerates the particular SCSI other device by sending a query to the corresponding storage device **14** through the associated SCSI adaptor **20** (step **400**). The storage device responds by returning its serial number and any other requested information to the PDD through the adaptor **20**. When the PDD receives the response, the PDD determines if it has already queried this device through another path to the device (steps **402**, **404**). The PDD thus checks if the serial number contained in the response matches a serial number contained in any previously received response.

If the serial number does not match any of the previously received serial numbers, the PDD creates a new SCSI-class device and "attaches" the device to the virtual SCSI adaptor (step **406**). The PDD then tells the plug and play manager that the configuration of the virtual SCSI adaptor has changed (step **408**). The PDD also internally maps the storage device **14** to the newly created SCSI-class device, and maps the SCSI adaptor **20** to the virtual adaptor (steps **410**, **412**).

If the serial number in the response from the associated storage device matches a serial number in a previous response, the PDD determines that the SCSI bus is dual initiated (step **414**). The PDD then internally maps the storage device to the corresponding SCSI-class device attached to the virtual SCSI adaptor (step **410**). Further, the PDD internally maps the associated SCSI adaptor, in the example, adaptor **20**, to the virtual SCSI adaptor (step **412**).

After mapping the SCSI other device to the appropriate SCSI-class device that is attached to the virtual SCSI adaptor, the PDD notifies the plug and play manager that no devices are attached to the SCSI other device (step **416**).

The PDD operates in the same manner in response to the requests by the plug and play manager to enumerate each of remaining the SCSI other devices attached to the SCSI adaptor **20**. The PDD also operates in the same manner in response to the requests by the plug and play manager to enumerate each of the SCSI other devices attached to the SCSI adaptor **22**. When the PDD has responded to the last enumeration request, the PDD has internally mapped the SCSI other devices to a single set of SCSI-class devices that are attached to the virtual SCSI adaptor.

Referring also to FIG. **5**, when the plug and play manager is notified by the PDD that the configuration of the virtual SCSI adaptor ahs changed, the plug and play manager requests that the PDD enumerate the devices connected to the virtual SCSI adaptor (step **500**). In response to the request from the plug and play manager, the PDD provides a list of the SCSI-class devices then known to the PDD (step **502**). The plug and play manger then consults its table **33** to assign to the listed SCSI-class devices the appropriate SCSI-class drivers **40** (FIG. **3**) (step **504**). The plug and play manager thus assigns an appropriate disk device driver to each SCSI-disk device and an appropriate tape device driver to each SCSI-tape device. The plug and play manager the, in a conventional manner, asks the assigned SCSI-class drivers **40** to separately enumerate each SCSI-class device (step **506**).

In response to a request from the plug and play manager, a given SCSI-class driver directs a request to read partition information and so forth to a particular SCSI-class device on the list. The request is directed to the SCSI-class device through the virtual SCSI adaptor. The PDD thus intercepts the request and re-directs it through a selected SCSI adaptor **20** or **22** to the associated storage device **14**. The selected SCSI adaptor then acts in a conventional manner to provide the requested access to the disk or tape device. The SCSI-class drivers **40** continue to enumerate each of the SCSI-class devices listed as attached to the virtual SCSI adaptor, and the PDD continues to direct associated requests through the selected SCSI adaptor to the corresponding storage devices **14**.

When the SCSI-class drivers **40** have enumerated the SCSI-class devices and provided the necessary information to the plug and play manager **32** and the mini-port drivers **36**, as appropriate, the plug and play manager and/or the mini-port driver then operate in a conventional manner to identify the SCSI disk devices and SCSI tape devices to the operating system (step **508**). The operating system then assigns a set of device objects to the SCSI disk and tape devices in a conventional manner. Non-storage devices on the SCSI bus, depicted in FIG. **3** as blocks **15**, are treated in a conventional manner by the mini-port driver. These

devices are similarly assigned appropriate SCSI class drivers **42** (FIG. **3**) and device objects, also in a conventional manner.

The operations of the mini-port driver and the PDD ensure that each storage device will be assigned a single device object, regardless of how many SCSI adaptors provide access to the storage device. When a generic data transfer command is addressed to a given storage device **14** using the assigned device object, the PDD **38** intercepts the command and redirects it to the corresponding storage device through the selected one of the SCSI adaptors **20** or **22**. The selected SCSI adaptor then operates in a conventional manner, to translate the command to a device-specific command, and so forth.

Referring now to FIG. **6**, the SCSI adaptors **20** and **22** may be single-ported and connect, respectively, to one SCSI bus as depicted in FIG. **1**. Alternatively, as depicted in FIG. **6**, the SCSI adaptors may be dual-ported and thus each connect to redundant SCSI busses **16** and **17**. The two SCSI adaptors **50** and **52** depicted in the drawing each have primary and secondary ports $\mathbf{50}_0$ and $\mathbf{50}_1$ and $\mathbf{52}_0$ and $\mathbf{52}_1$, respectively. The primary port for each adaptor is, for example, the port with the lowest address, namely, $\mathbf{50}_0$ or $\mathbf{52}_0$. The hardware is configured such that the primary port $\mathbf{50}_0$ of the SCSI adaptor **50** connects to one SCSI bus, in the example, the bus **16**, and the secondary port $\mathbf{50}_1$ of the adaptor connects to the second SCSI bus **17**. The second of the SCSI adaptors has its primary port $\mathbf{52}_0$ connected to the SCSI bus **17** and its secondary port $\mathbf{52}_1$ connected to the SCSI bus **16**.

With dual-ported SCSI adaptors, the PDD **38** selects one SCSI adaptor for use on one bus and another for use on the other bus, in order to load share between the two SCSI adaptors. In the example, the PDD selects the SCSI adaptor **50** for use on the SCSI bus **16**, which is connected to the primary port $\mathbf{50}_0$ of the adaptor. Similarly, the PDD selects the SCSI adaptor **52** for use on the SCSI bus **17**. The PDD could instead select to use the adaptors on the busses that are connected to the secondary port of each adaptor, with the same load sharing result.

Referring now to FIGS. **3** and **7**, if the selected SCSI adaptor, for example, adaptor **20**, fails, the plug-and-play manager **32** receives a message from a hardware monitoring subsystem (not shown) that something in the storage subsystem has changed at the PCI bus level. Alternatively, the error message may be sent by the PDD **38**, which receives error messages in response to requests sent through the failed adaptor (step **700**). In response, the plug-and-play manager **32** generates an interrupt and asks the PCI bus driver **32** to again enumerate the PCI bus (step **702**). The PCI bus driver now identifies only one SCSI adaptor, namely, the operative adaptor **22** (step **704**).

The plug-and-play manager **32** next removes its prior listing of the failed SCSI adaptor **20** and the associated SCSI other devices (step **706**). The plug and play manager then notifies the PDD **38** of the removal of each SCSI other device attached to the failed adaptor, and notifies the mini-port driver of the removal of the failed SCSI adaptor (steps **708–710**).

The plug and play manager still sees the storage devices **14** as attached to the virtual SCSI adaptor, and thus, the plug and play manager does not see any change in the way data transactions are made with those devices. Accordingly, the plug and play manager determines that adaptor failure does not affect the data transfer operations, and no error message is required to be sent.

Referring now also to FIG. **8**, when the SCSI other devices attached to the SCSI adaptor **20** are removed by the plug and play manager, the PDD **38** selects the operative SCSI adaptor **22** for use in the data transfer operations (steps **800–802**). Further, for those devices that are disk devices, the PDD controls a reissue, through the operative SCSI adaptor **22**, of any requests that were directed through the failed adaptor **20** are now associated with error messages (step **804**). For those devices that are tape devices, the PDD passes information relating to the failed requests back through the system to the applications that issued the requests (step **806**). The applications then re-issued the requests in a conventional manner.

After failures inoperative SCSI adaptor may be rep , replaced and/or removed, without altering the way in which the system components **12** perform future data transfer operations. If the failed SCSI adaptor is repaired or replaced, the adaptor is enumerated and the PDD changes its internal mappings to the virtual SCSI adaptor and the associated SCSI-class devices attached to the virtual SCSI adaptor, to again include the redundant path to the devices. The PDD may then change its adaptor selection, to revert to the repaired or replaced adaptor for load sharing.

Instead of using the mini-port driver essentially to disguise the storage devices **14** as SCSI other devices, the system may use a filter driver that is inserted into the driver stack of the storage devices to intercept and respond to SCSI bus enumeration requests. In the response, the filter driver identifies the storage devices as a special class of device that is handled by the PDD, and the PDD then operates in the manner described above. This allows the mini-port driver to operate in a conventional manner, to identify various non-storage devices that fall into the conventional SCSI other class. In any event, conventional SCSI adaptors are used.

The foregoing description has been limited to a specific embodiment of this invention. It will be apparent, however, that variations and modifications may be made to the invention, such as the redundant SCSI bus adaptors may be bus adaptors for busses such as the USB, IEEE 1394, IBM serial storage architecture bus, Infiniband, IBM ESCON, or fiber channel, with the attainment of some or all of its advantages. Therefore, it is the object of the appended claims to cover all such variations and modifications as come within the true spirit and scope of the invention.

What is claimed is:

1. A computer system including:

A. one or more storage devices connected to a first bus;

B. one or more system components that connect to a second bus and communicate with the storage devices;

C. one or more bus adaptors for transferring communications to and from the second bus and the storage devices on the first bus;

D. a port duplex driver for mapping one or more communications paths to the storage devices through the one or more bus adaptors to a communication path through a virtual bus adaptor,

E. object means for assigning to each storage device on the first bus a device object that corresponds to the communications path through the virtual bus adaptor, the object means informing the system components of the assigned device objects; and

F. the port duplex driver further re-directing to a selected one of the bus adaptors communications from the system components that include the assigned device objects.

2. The computer system of claim 1 further comprising:

a. a mini-port driver that identifies the storage devices as belonging to a given special class of device, and

b. a plug and play manager that associates the given special class of device with the port duplex driver.

3. The computer system of claim 1 wherein the first bus is a SCSI bus and the second bus is a system I/O bus.

4. The computer system of claim 3 wherein the system I/O bus is a PCI bus.

5. The computer system of claim 1 wherein the port duplex driver changes the selection of the bus adaptor from a previously selected bus adaptor that has failed to an operative bus adaptor.

6. The computer system of claim 5 wherein the port duplex driver re-issues to the operative bus adaptor the communications that were directed to the failed bus adaptor after the failure.

7. The computer system of claim 1 further comprising:

G. additional storage devices connected to another first bus,

H. the one or more bus adaptors are dual ported, and

I. the port duplex driver selects one bus adaptor for use on one first bus and a different bus adaptor for use on the other first bus.

8. A method of operating a computer system, the method comprising the steps of:

A. determining that one or more storage devices are accessible over a first communications bus through one or more bus adaptors;

B. mapping the one or more bus adaptors to a virtual bus adaptor and presenting to system components that communicate with the storage devices a communication path through the virtual bus adaptor to the storage devices;

C. assigning to each storage device on the first communications bus a device object that corresponds to the communications path through the virtual bus adaptor;

D. informing the system components of the assigned device object, and

E. re-directing to a selected one of the bus adaptors the communications that are directed through the virtual bus adaptor to the storage devices.

9. The method of claim 8 wherein the step of determining that the one or more storage devices are accessible over the first communication bus includes:

i. sending queries to the storage devices through each of the one or more bus adaptors and receiving responses from the storage devices through each of the one or more bus adaptors,

ii. identifying the storage devices as devices that are controlled by a port duplex driver,

iii. reporting by the port duplex driver that the storage devices are accessible through the virtual bus adaptor.

10. The method of claim 9 wherein the step of reporting by the port duplex driver includes

a. determining that the one or more bus adaptors provide redundant paths to the storage devices, and

b. mapping the bus adaptors that provide the redundant path to the same virtual bus adaptor.

11. The method of claim 10 wherein the step of determining redundant paths further includes

c. identifying the storage devices as special devices that are accessible through each of the bus adaptors; and

d. associating the special devices with the port duplex driver.

12. The method of claim 11 wherein the port duplex driver:

e. in the step of reporting further includes reporting the virtual bus adaptor and the storage devices as devices to which the system assigns device objects, and

f. in the step of re-directing further includes re-directing to a selected bus adaptor the communications that include the device objects that are assigned to the storage devices.

13. The method of claim 9 wherein the step of mapping further includes mapping a newly added bus adaptor to the virtual bus adaptor if the newly added bus adaptor provides a redundant path to the storage devices.

* * * * *